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WARTIME REPORT

ORIGINALLY ISSUED

November 1944 as
Memorandum Report L4K14

ACCELERATIONS AND BOTTOM PRESSURES MEASURED ON A B-24D AIRPLANE IN A DITCHING TEST

By Margaret F. Steiner

Langley Memorial Aeronautical Laboratory
Langley Field, Va.

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

MEMORANDUM REPORT

for the

Army Air Forces, Air Technical Service Command

ACCELERATIONS AND BOTTOM PRESSURES MEASURED ON A B-24D AIRPLANE IN A DITCHING TEST

By Margaret F. Steiner

SUMMARY

During the full-scale ditching of an Army B-24D airplane in the James River, accelerations near the center of gravity and bottom pressures were measured. The data are presented in the form of time-history plots of the recorded longitudinal, normal, and transverse accelerations and of the bottom pressures.

The airplane contacted in a tail-down attitude, barely left the water, entered again and rocked forward so that the nose and most of the fuselage dug in deeply. During the first impact the high pressure area started at the rear of the bomb-bay section and progressed to a point near the empennage and on the second impact it progressed forward from a point just aft of the bomb bay until most of the nose was subjected to water load.

In most cases the maximum recorded pressure at each station exceeded the capacity of the instruments being greater than 30 to 50 pounds per square inch.

The maximum recorded acceleration was 2.7g acting in the rearward direction along the longitudinal axis. The accelerations along other axes were negligible.

INTRODUCTION

The various aerial combat units operating over water have been faced with the serious problem of making emergency landings on water in such a manner as to minimize hazard to personnel.

For several months the NACA Laboratory at Langley Field, Va., has been conducting ditching tests with models of service airplanes and the Hydrodynamics Division in cooperation with the Army Liaison Office is now participating in a program comprising ditchings of full-size B-24D airplanes. This program was initiated by the Army Air Forces, Air Technical Service Command.

The purposes of the program were to investigate the agreement between full-scale and model tests to study the inherent ditching qualities of a B-24D airplane and to provide, if possible, a safer method of ditching the subject airplane.

This report presents only that portion of the data from the first ditching which was to be used to roughly establish the accelerations experienced by the pilot and the amount of water pressure to which the fuselage structure was subjected during the ditching.

APPARATUS AND PROCEDURE

Figure 1 is a photograph of the B-24D airplane prepared for ditching. The weight of the airplane was about 44,100 pounds and the center of gravity was located at 30.9 percent of the mean aerodynamic chord.

The bomb doors and gun-turret well were replaced by $\frac{1}{8}$-inch steel plating; the camera hatch and plexiglass sections of the nose were replaced by $\frac{3}{32}$-inch steel plating. Wooden bracings and steel reinforcing ribs were added throughout the fuselage structure.

Among the instruments used in this test were two standard NACA air-damped three-component accelerometers and two air-damped single-component accelerometers which also recorded the impulses from two $\frac{1}{10}$-second timers on the airplane and from a $\frac{1}{2}$-second timer on the shore

which transmitted its impulses to the airplane by means of radio. The accelerometers were rigidly mounted in the life raft compartment as close to the center of gravity as possible and were subject to local disturbances as well as to the main accelerations of the airplane. The ranges and vane frequencies of the accelerometers are listed in table I. The two three-component accelerometers were so oriented that they measured longitudinal, transverse, and normal accelerations and the two single-component accelerometers were oriented so that they measured accelerations along the longitudinal axis.

Also used were two photo observers which photographed the airspeed indicator, the flap-position indicator, the gyro horizon, and the directional gyro. The photo observers were mounted on watertight bases on the top of the wing in the life-raft compartments.

Twenty pressure recorders, all standard NACA instruments with corrugated diaphragms, were used in the test. The diaphragms had a diameter of $1\frac{1}{8}$ inches and were mounted flush with the skin. Their location is shown in figure 2 and a typical installation is shown in figure 3.

The range of each pressure instrument and the timer from which it received its impulse is listed in table II. Timer number 2 operated satisfactorily throughout the run but timer number 1 failed after the first impact so an approximate time scale was devised for those records receiving their impulses from this timer.

Inasmuch as a limited number of 50- and 100-pound instruments was available, they were located so that instruments with greater positive range were at points where greatest positive pressures were expected and the instruments with greater negative range were at points where greatest negative pressures were expected. Table II indicates that the range of most of these instruments was not quite sufficient to allow the recording of the maximum pressures, which fact is noted on the plots.

All instruments in the airplane were controlled by a single master switch in the pilot's compartment which was thrown prior to the time that the airplane touched the water.

Four phototheodolites stationed on the James River Bridge recorded photographically a time history of the ship's progress during the ditching and made available the values of vertical velocity and trim angle during the approach.

The airplane made a tail-down flared landing in the James River after an approach with partial power and with flaps down. It contacted at about 146 feet per second, trimmed to a high angle as it settled in slightly, then left the water for an instant, entered again and plowed through the water with most of the fuselage below the water surface.

PRECISION OF DATA

The following values of the probable accuracy of the measurement consider variation between repeat readings.

Component of acceleration, g	
Normal	±0.20
Longitudinal	±0.20
Transverse	±0.20
Pressure, lb/in.^{2} (in an intact instrument)	±2

Inasmuch as the precision of the results obtained from the pressure recorders is affected by the condition of the gages during the run, a summary of the operational efficiency and failures of the instruments follows.

Instruments numbers 56, 50, 59, and 46 operated satisfactorily throughout the run and instruments numbers 41, 61, and 44 operated adequately except for the fact that the recorded negative pressures exceeded the small negative range of the instruments causing the recording stylus to go off scale sometime during the run.

Instruments numbers 58, 51, and 52 recorded only during the first portion of the run, instrument number 58 being crushed during the first impact as

the fuselage structure was badly deformed. Early in the second impact the two latter instruments were no longer subjected to pressure.

Instruments numbers 48 and 53 apparently recorded satisfactorily during the second impact until the skin and supporting structure were deformed inward. Instrument number 48 was bent into the hull and was shielded from water pressure during the latter part of the run while instrument number 53 was bent into a position perpendicular to the fuselage bottom.

Instruments numbers 57, 45, 43, and 42 all appeared to have failed upon first contact with the water. The diaphragm of instruments numbers 57 and 43 received a permanent set of 1/8 inch. The recording stylus on instruments numbers 42 and 45 failed as a result of hitting the stop immediately after first contact. Although these four instruments did not record time histories, they did record a pressure value which must have been exceeded.

RESULTS

Figure 4 is a photograph of a typical pressure record and figure 5 is a photograph of one of the longitudinal accelerometer records.

Figure 6 presents the time history of normal (along the vertical axis of the airplane perpendicular to the fore and aft axis), transverse, and longitudinal (fore and aft axis of the airplane) accelerations measured near the center of gravity. The longitudinal components from the two three-component accelerometers are not presented since the majority of the values exceeded the range of the instruments. The accelerometer plots consist of faired curves which do not show vibrations recorded.

The time histories of the 20 pressure recorders are presented in figures 7 through 13. The records show pronounced vibrations but the estimated effective pressures are shown by the heavy faired lines. Negative pressures were indicated but the peak values were not always obtained since they exceeded the small negative

range of most of the instruments which was about 3 pounds per square inch. Pressure distributions along the center line of the bottom at successive instants of time are presented in figure 14.

Figure 15 presents the maximum pressures and the instant of time at which they occur.

Table III summarizes the landing condition with regard to flight parameters and seaway.

The pressure distribution holds for this reinforced airplane with its specific damage. The distribution would be different for a normal airplane in a ditching or for an airplane which remained undamaged. Figure 16 is a photograph of the B-24D fuselage bottom taken just after the airplane was retrieved from the James River. Note the damage in the nose-wheel area, the dent in the rear bomb doors, and the hole near bottom turret. Rudders were slightly damaged and the skin was indented over the lower half of the fuselage in a strip just in front of the empennage.

DISCUSSION OF RESULTS

The results indicate that the airplane first touched near the rear end of the bomb-bay section where pressures were developed which exceeded 50 pounds per square inch. Slight negative pressures developed toward the tail and as the airplane settled in it trimmed to a high positive angle. This trimming process may have been aided by small negative pressures on the tail over a substantial area.

Immediately after first contact the area just aft the $\frac{1}{8}$-inch steel plating was forced inward, the skin was crushed at a section of the fuselage tail near the rudder hinge line, and the rudders were damaged.

The airplane barely left the water and then touched again at a point near the aft end of the bomb-bay section from which point the pressure area gradually moved forward until the foremost portion of the fuselage was receiving water load. Positive pressures greater than 30 to 50 pounds per square inch were developed as

the airplane rocked forward with the port wing low. These high pressures failed the bottom area just in front of the walkway. As the nose plowed through the water the steel reinforcement over the bombardier's sighting window was dented at which time the maximum decelerations also occurred. The damage around the nose-wheel door section apparently weakened the structure to such an extent that the nose section was almost broken away from the rest of the airplane.

The fact that instrument number 52, which was on the left side, registered positive pressures at the same time that instrument number 51 on the right side registered negative pressures, indicated unsymmetrical loading of the fuselage.

Although the amount of spray thrown during the portion of the run in which the nose became immersed was large as compared with that observed during model tests and thus gave the impression of high accelerations, it may be observed from the time histories that the accelerations experienced were very moderate (fig. 6). The spray was caused not only by the immersion of the nose but also by the turning propellers and by the immersion of the left wing and engine nacelles.

The fact that the forward velocity was only about 60 feet per second when the nose finally touched late in the run is quite largely responsible for the low longitudinal decelerations.

CONCLUSIONS

1. The whole of the fuselage bottom was at some time during the ditching subjected to high local pressures.

2. The peak pressures appeared to be greater than 50 pounds per square inch over most of the bottom surface.

3. The maximum longitudinal deceleration was 2.7g, the maximum normal acceleration was 1.7g, and the maximum transverse acceleration was 0.5g.

Langley Memorial Aeronautical Laboratory
National Advisory Committee for Aeronautics
Langley Field, Va., November 14, 1944

TABLE I

ACCELEROMETER RANGES AND FREQUENCIES

NACA accelerometer serial number	Component	Range (g)	Natural vane frequency (cps)
409	Longitudinal	-1 to 1	13.7
	Transverse	-5 to 5	21.0
	Vertical	0 to 10	21.4
405	Longitudinal	-1 to 1	14.26
	Transverse	-5 to 5	20.0
	Vertical	0 to 10	21.0
286	Longitudinal	0 to 10	19.0
289	Longitudinal	0 to 10	20.89

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TABLE II

TABULATION OF INSTRUMENT RANGES AND TIMING SYSTEMS

NACA instrument number	Diaphragm range (lb)	Range	Timer number
42	30	Exceeded range	2
48	50	--------------	1
53	30	Exceeded range	2
43	50	------do.-----	1
44	50	------do.-----	2
45	50	------do.-----	1
46	50	------do.-----	2
59	100	--------------	1
50	50	Exceeded range	2
56	50	------do.-----	1
57	30	------do.-----	1
62	50	------do.-----	2
60	50	------do.-----	1
52	30	------do.-----	2
51	30	------do.-----	1
54	-20, 80	--------------	2
55	-20, 80	--------------	1
58	-20, 80	--------------	2
41	50	--------------	1
61	30	--------------	2

Note: Timer 1 failed to operate after first impact. Reasonable time intervals were assumed for remaining portion of record in the form of extrapolations based on constant film speed.

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TABLE III

FLIGHT PARAMETERS AND SEAWAY CONDITIONS

AT TIME OF CONTACT

Wave height, in.	0
Wind velocity, mph	5
Direction of wind relative to path from the right, deg	45
Weight of airplane, lb	44,100
Angle of fuselage reference line at contact, deg	7.5
Angle of incidence of wing with fuselage reference line, deg	3
Airspeed, mph	98
Probable water speed, mph	98
Vertical velocity, ft/sec	1.8
Tide velocity from the left, mph	1/2

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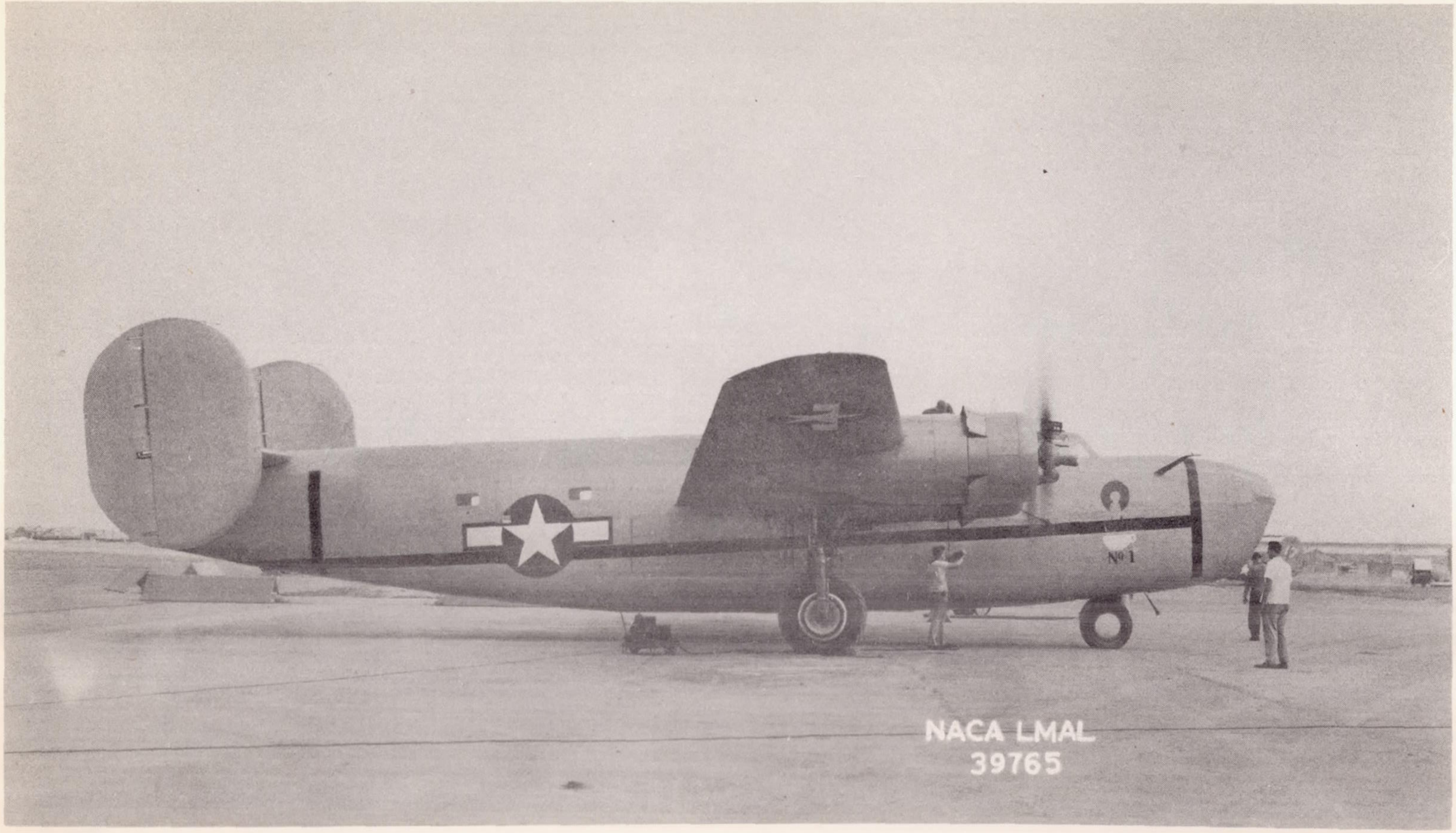

Figure 1.- Photograph of an Army B-24D airplane prepared for a ditching.

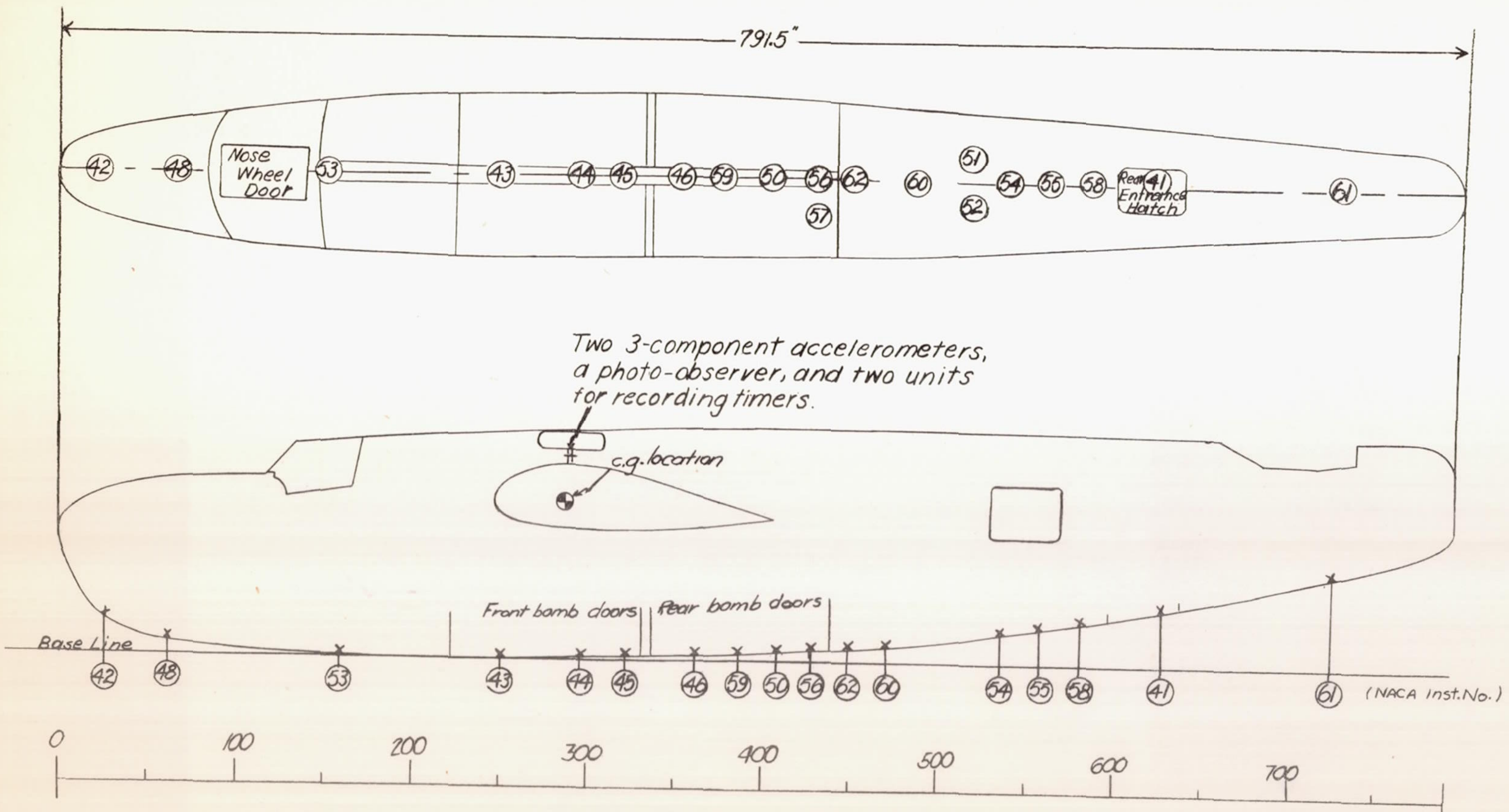

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Figure 2.- Location of the instruments on the B-24-D airplane with reference to existing structure.

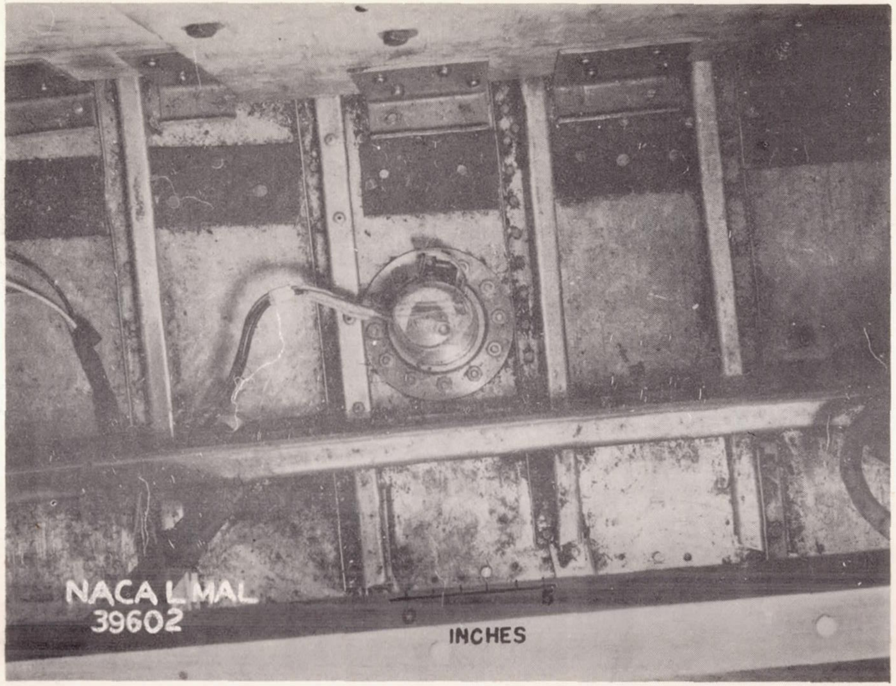

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Figure 3.- Photograph of a typical installation of a time-history pressure recorder. Film magazine is partly removed from instrument.

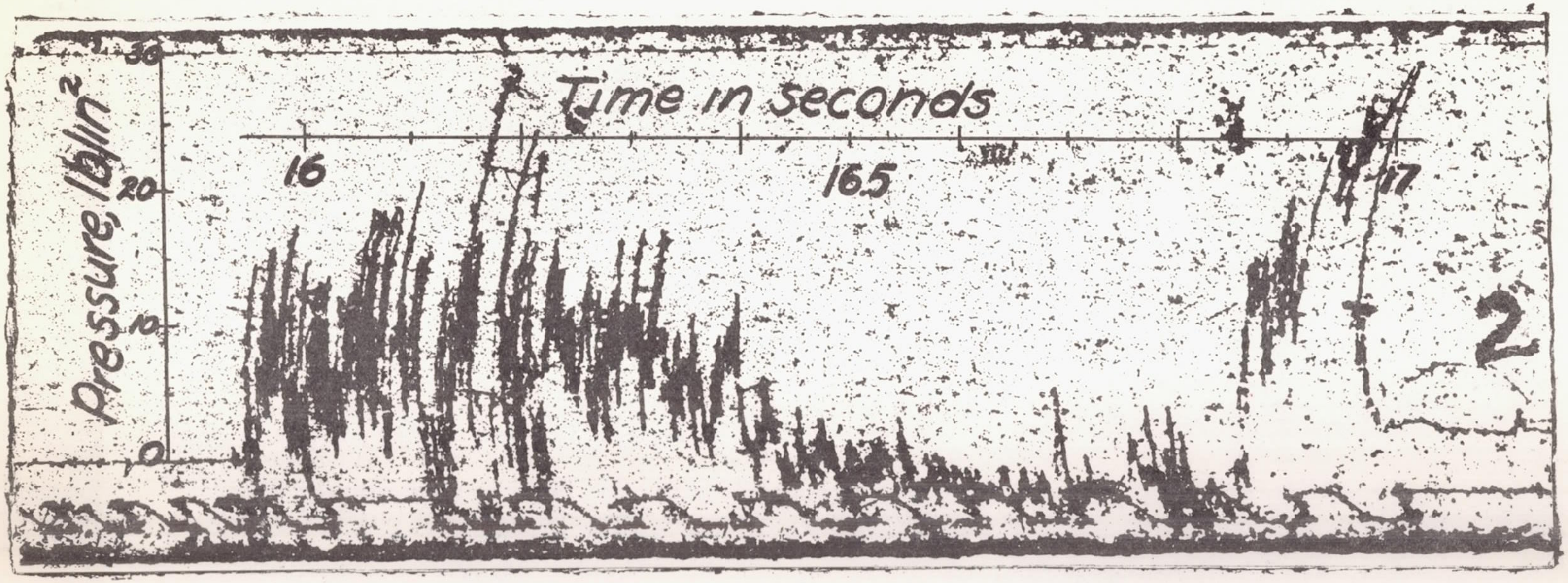

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Figure 4.- Photograph of a typical time history pressure record (1/10 second time impulses indicated).

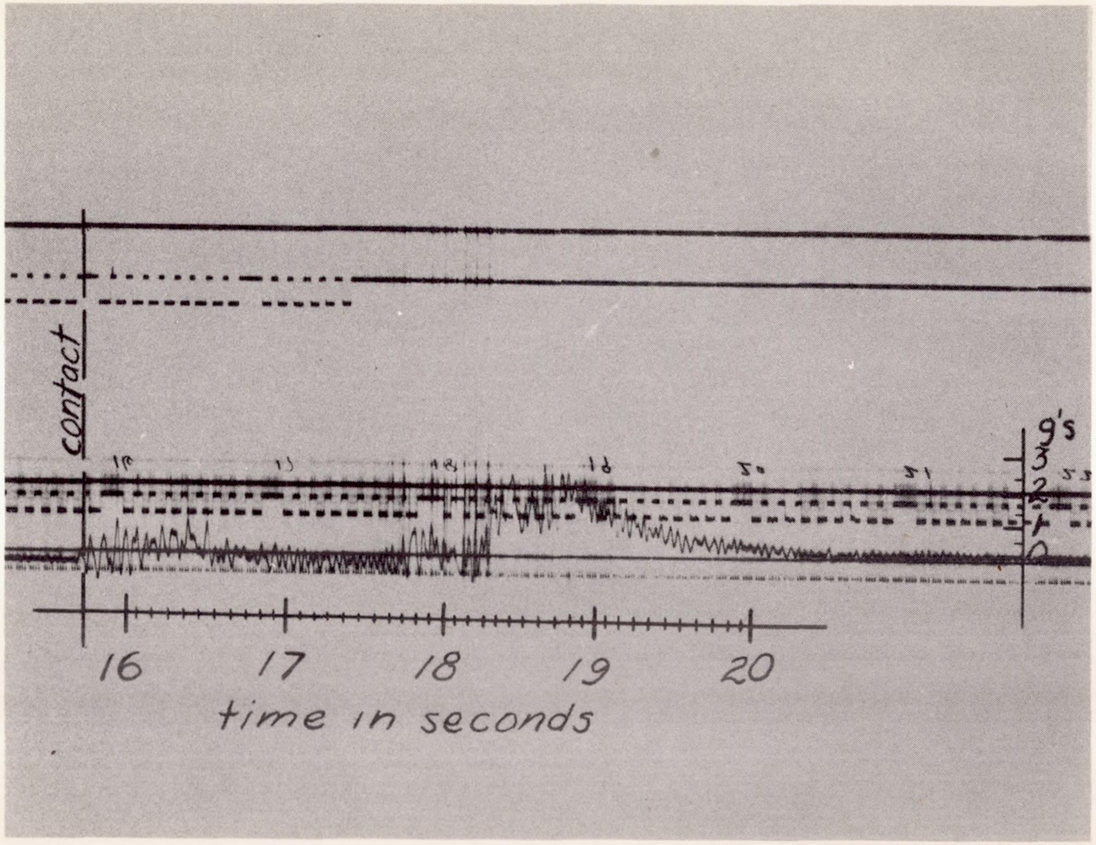

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Figure 5.- Photograph of a typical longitudinal accelerometer record.

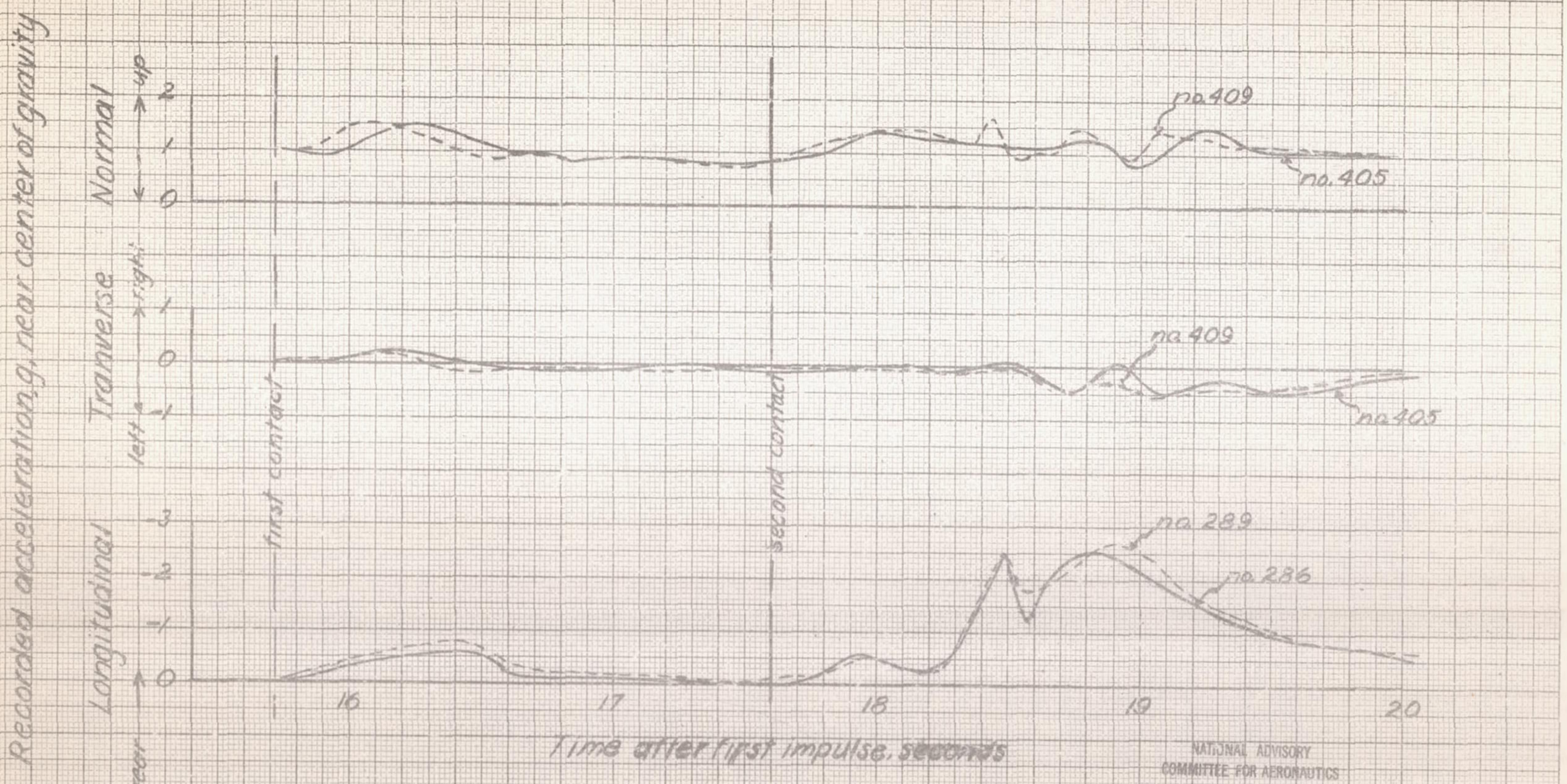

Figure 6.- Time histories of longitudinal, tranverse, and normal accelerations near the center of gravity of the B-24D airplane during a ditching test.

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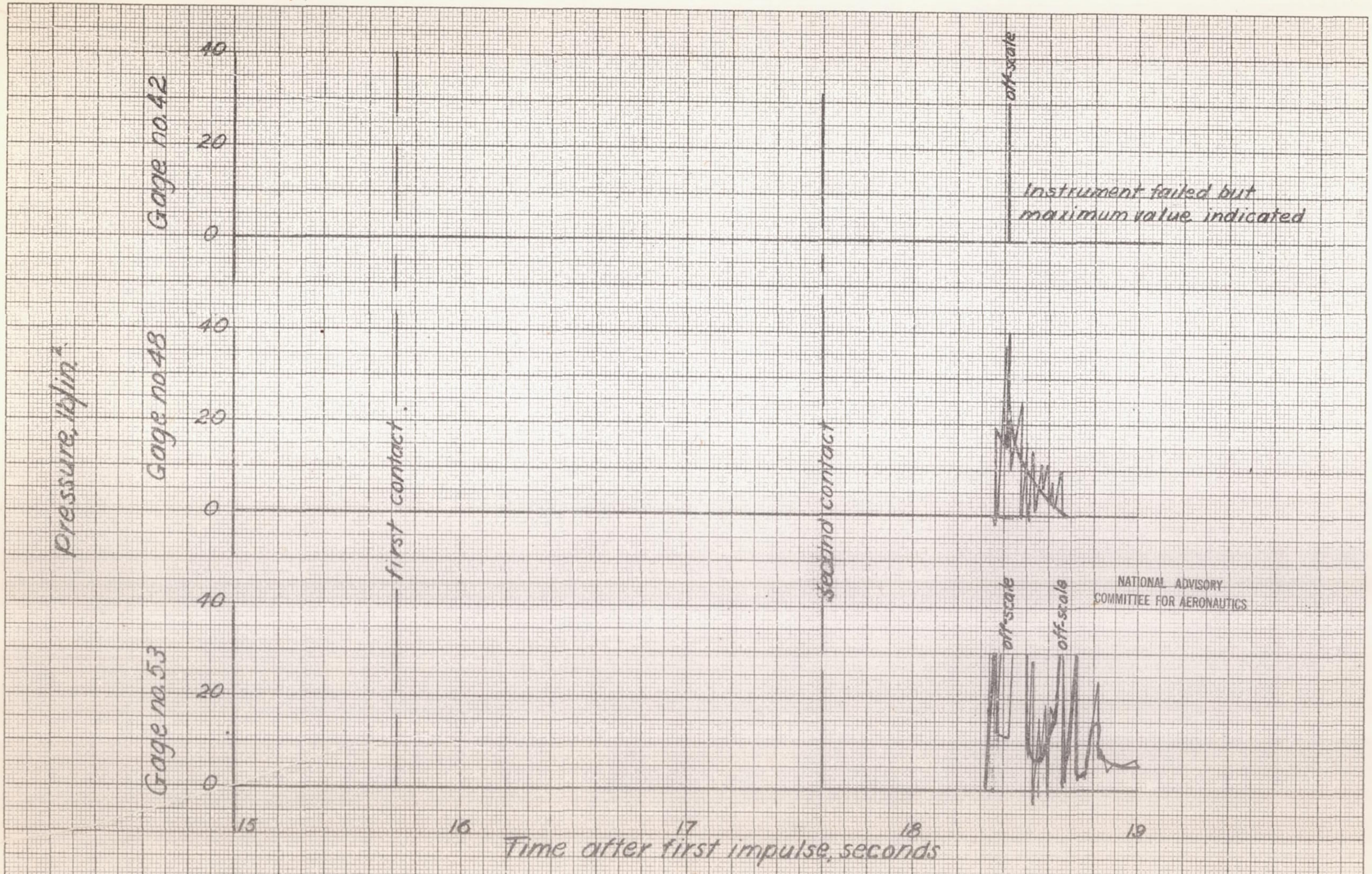

Figure 7.- Time histories of bottom pressures. Stations .15 - 1.60

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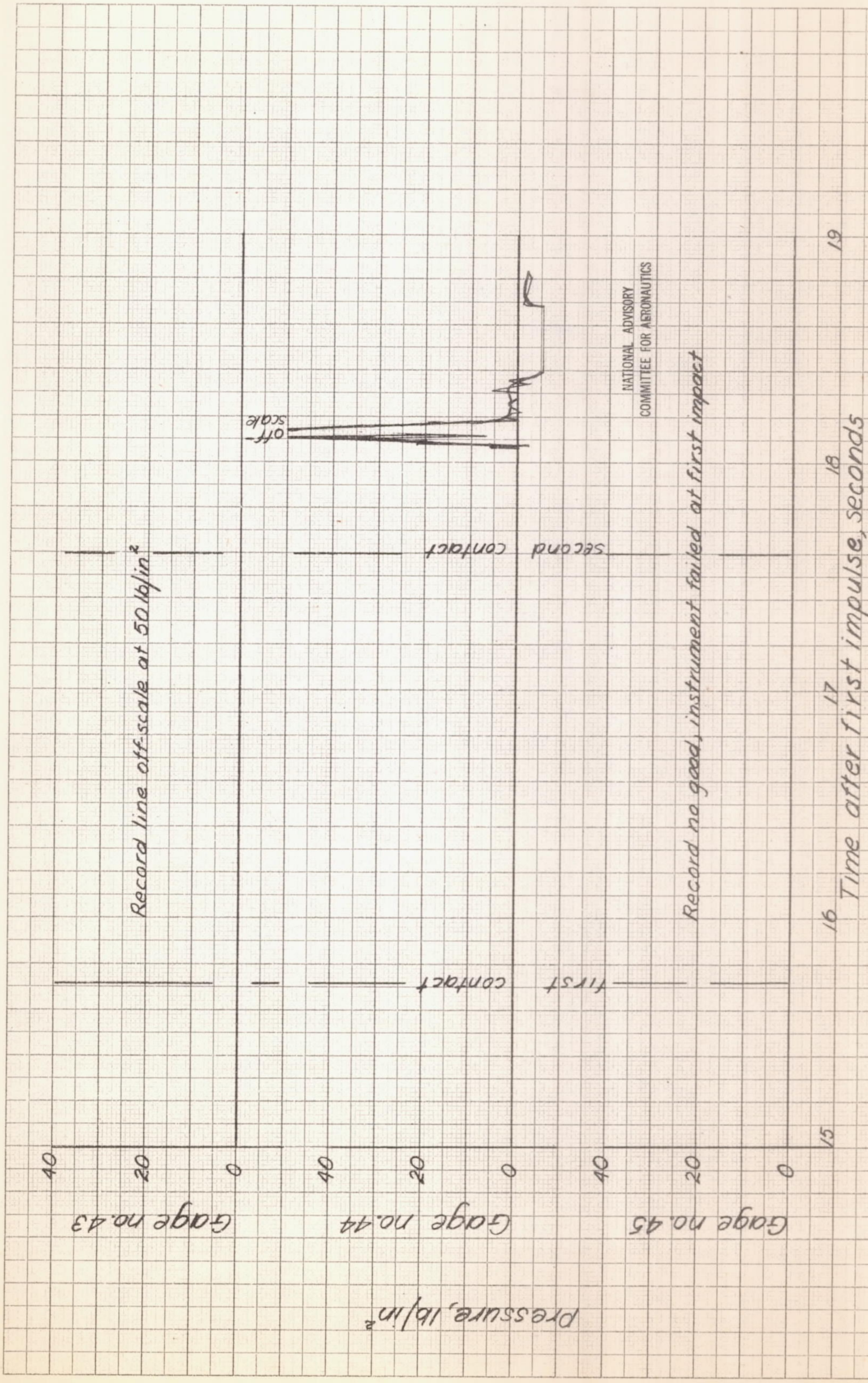

Figure 8 - Time histories of bottom pressures. Stations 255-314

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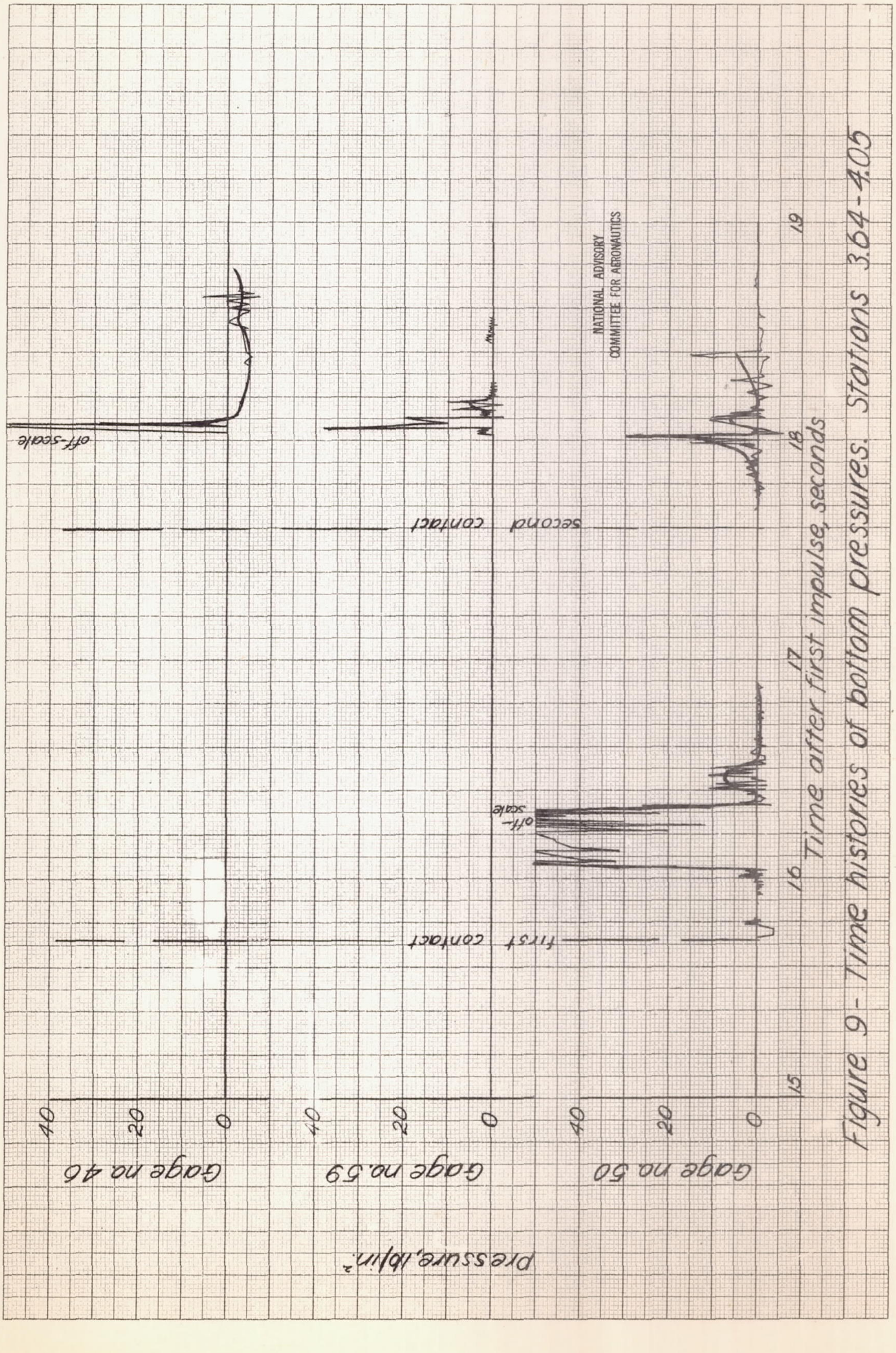

Figure 9- Time histories of bottom pressures. Stations 3.64-4.05

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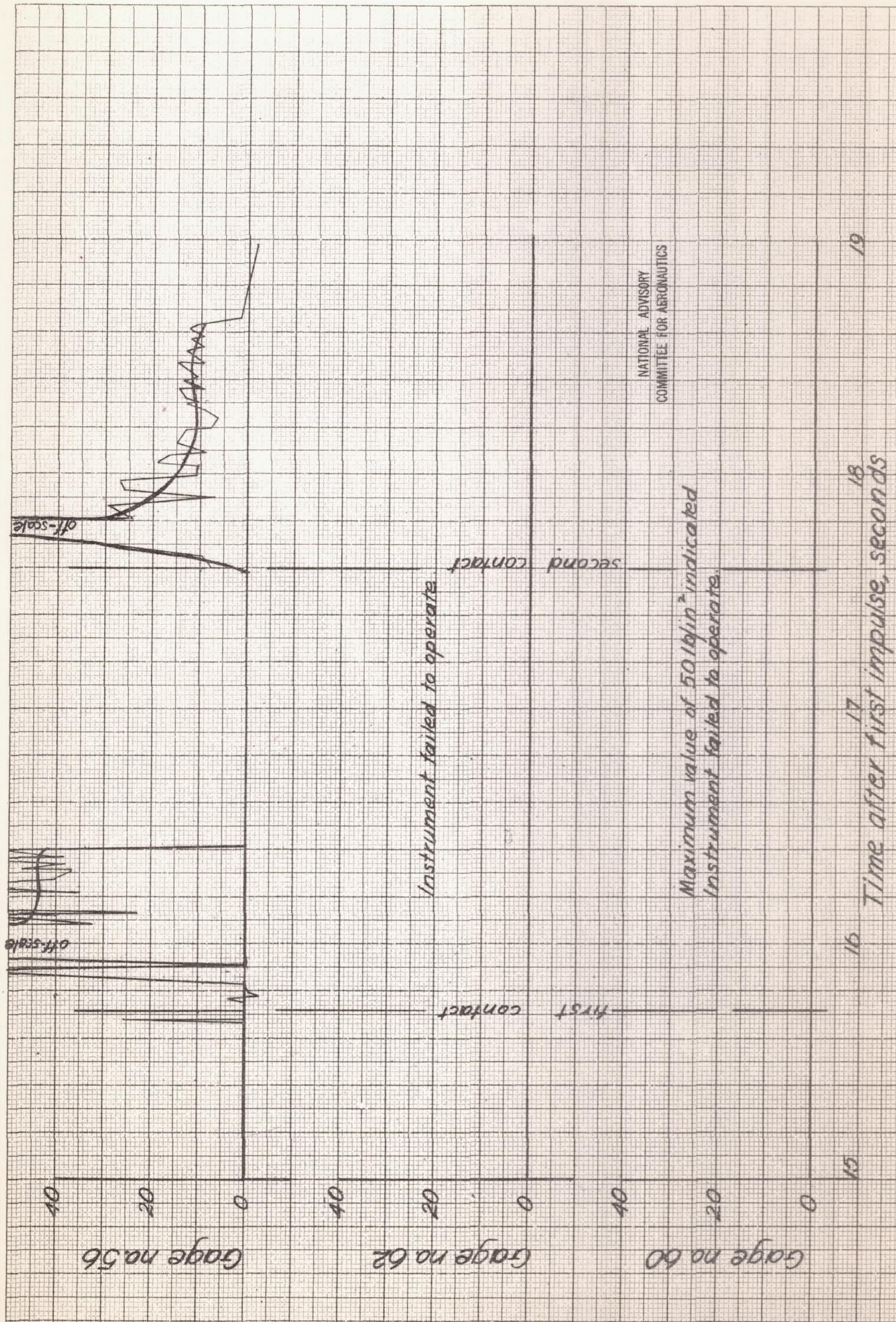

Figure 10- Time histories of bottom pressures. Stations 4.30-4.72

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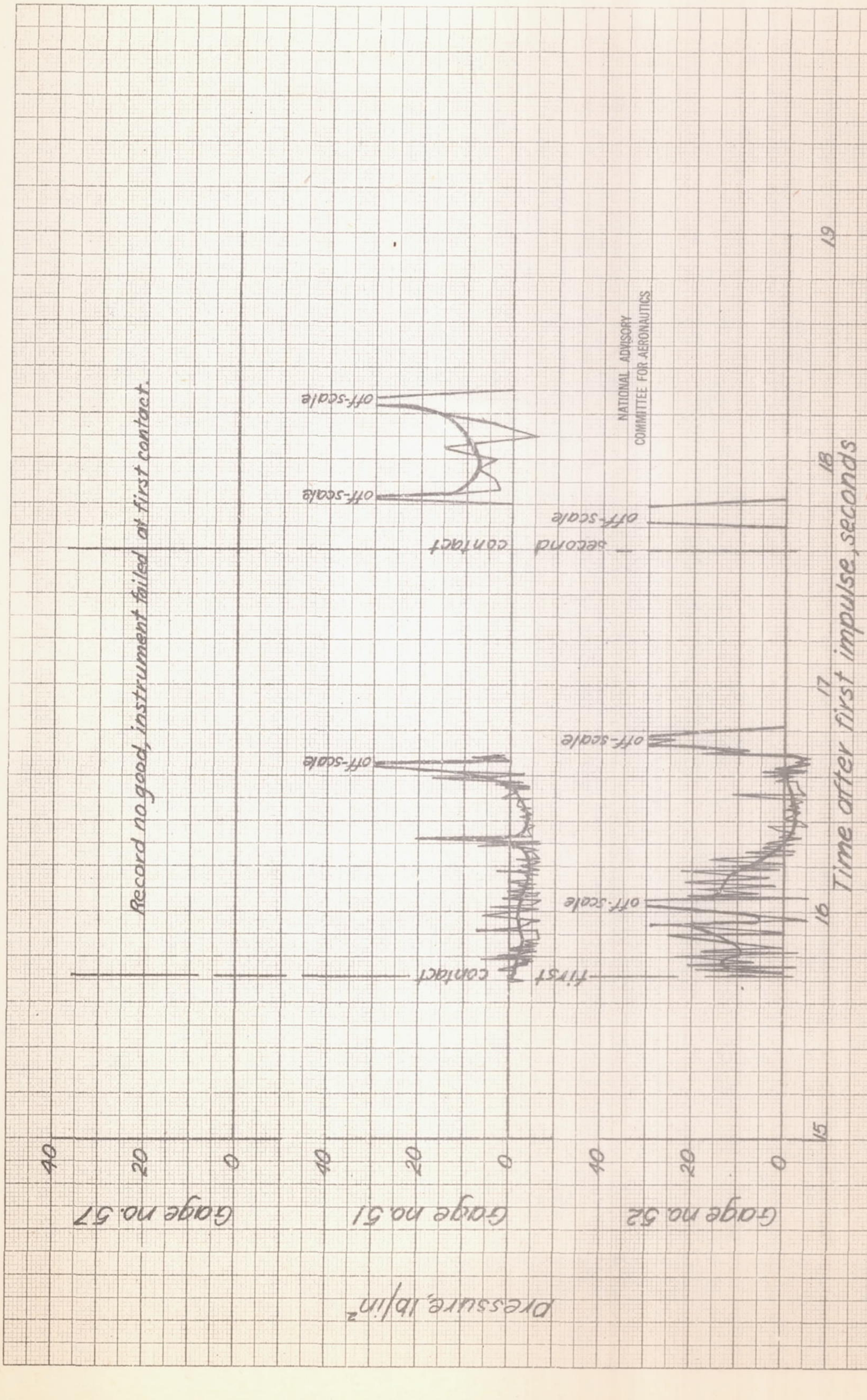

Figure 11.- Time histories of bottom pressures. Stations 4.30-5.00.

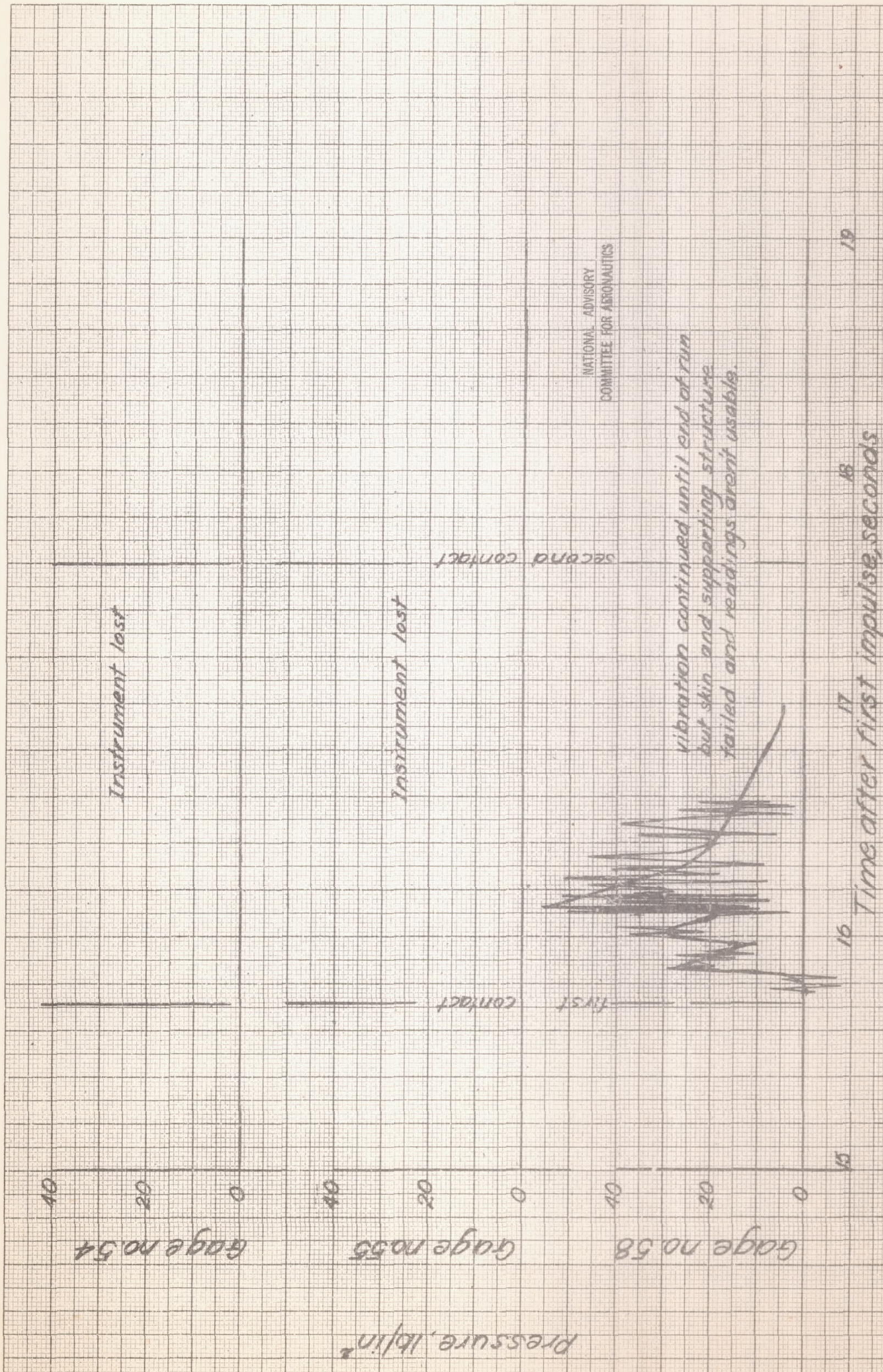

Figure 12.- Time histories of bottom pressures. Stations 540-585

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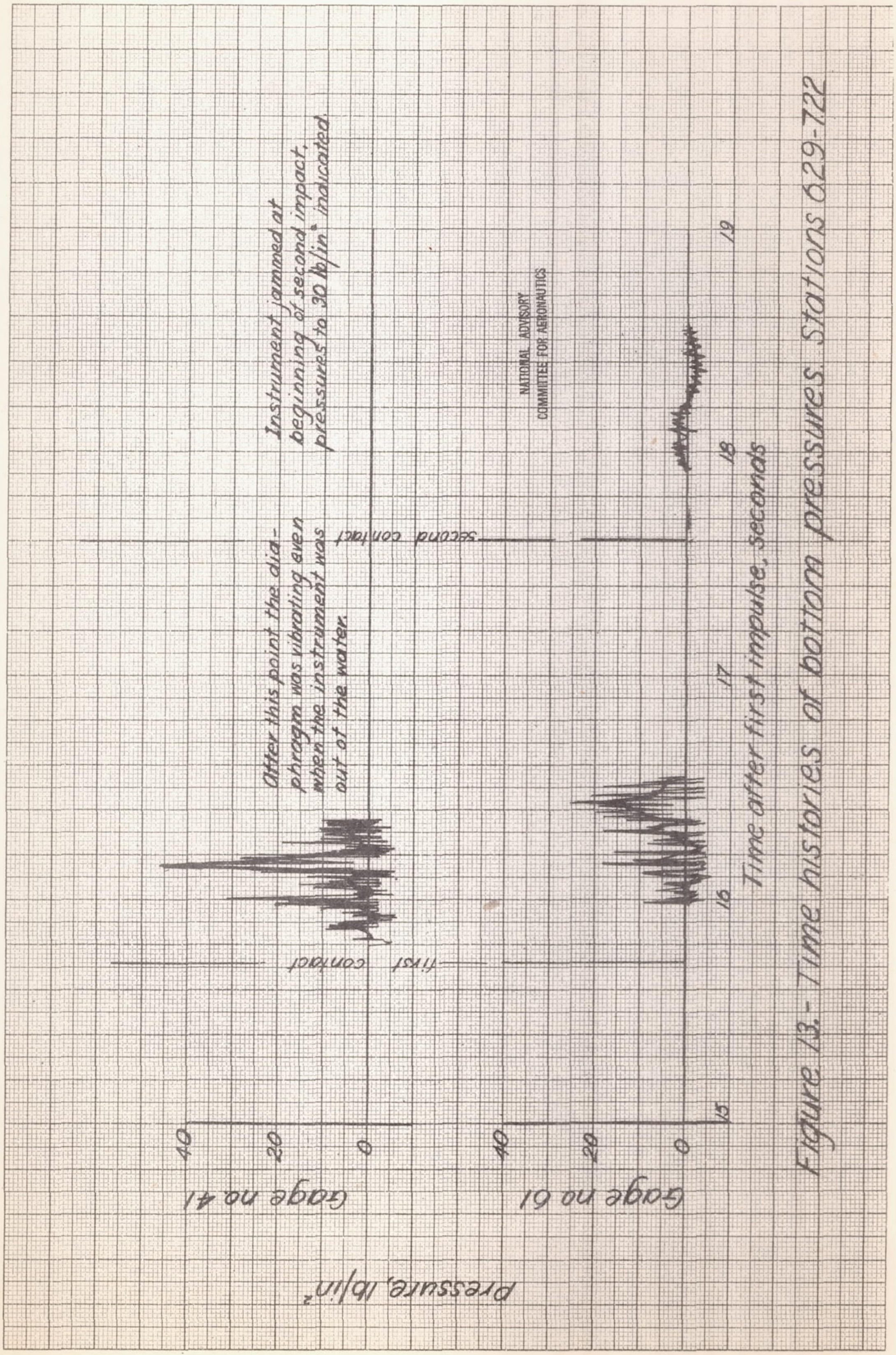
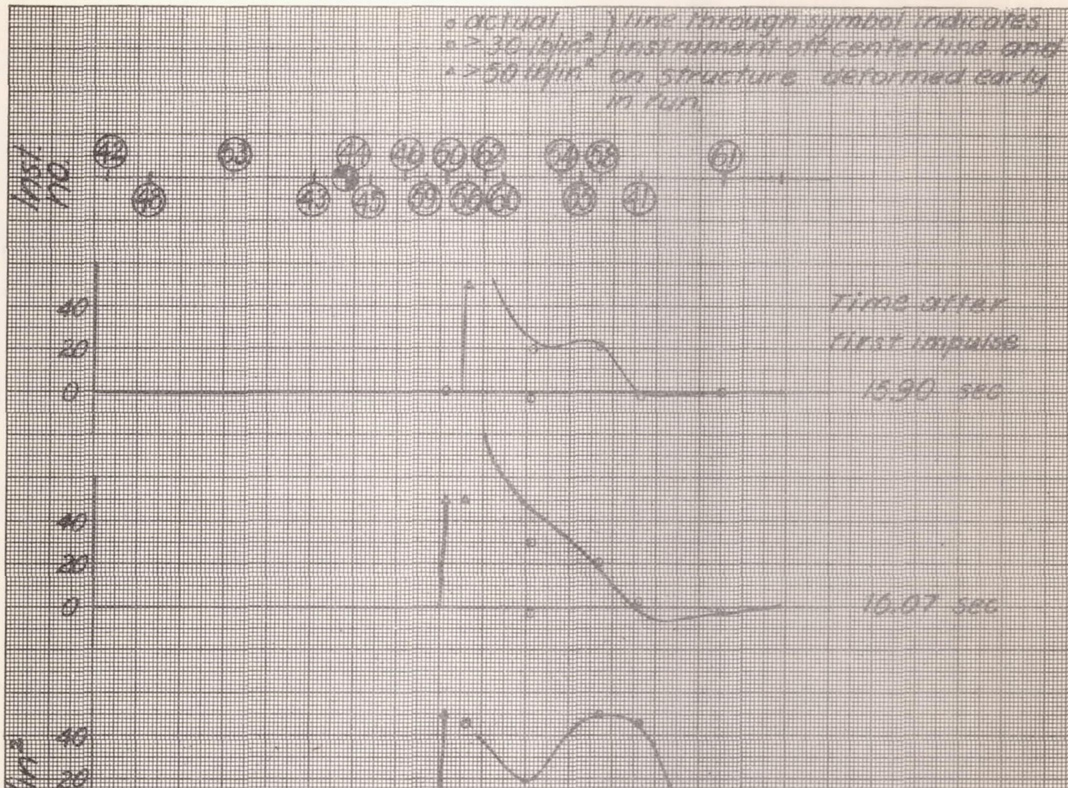


Figure 13.- Time histories of bottom pressures Stations 629-722



(a) 15.72 sec to 16.3 sec.

Figure 14.- Pressure distribution at successive instants of time along the center line of the fuselage bottom

Note: Fairing is an estimation.

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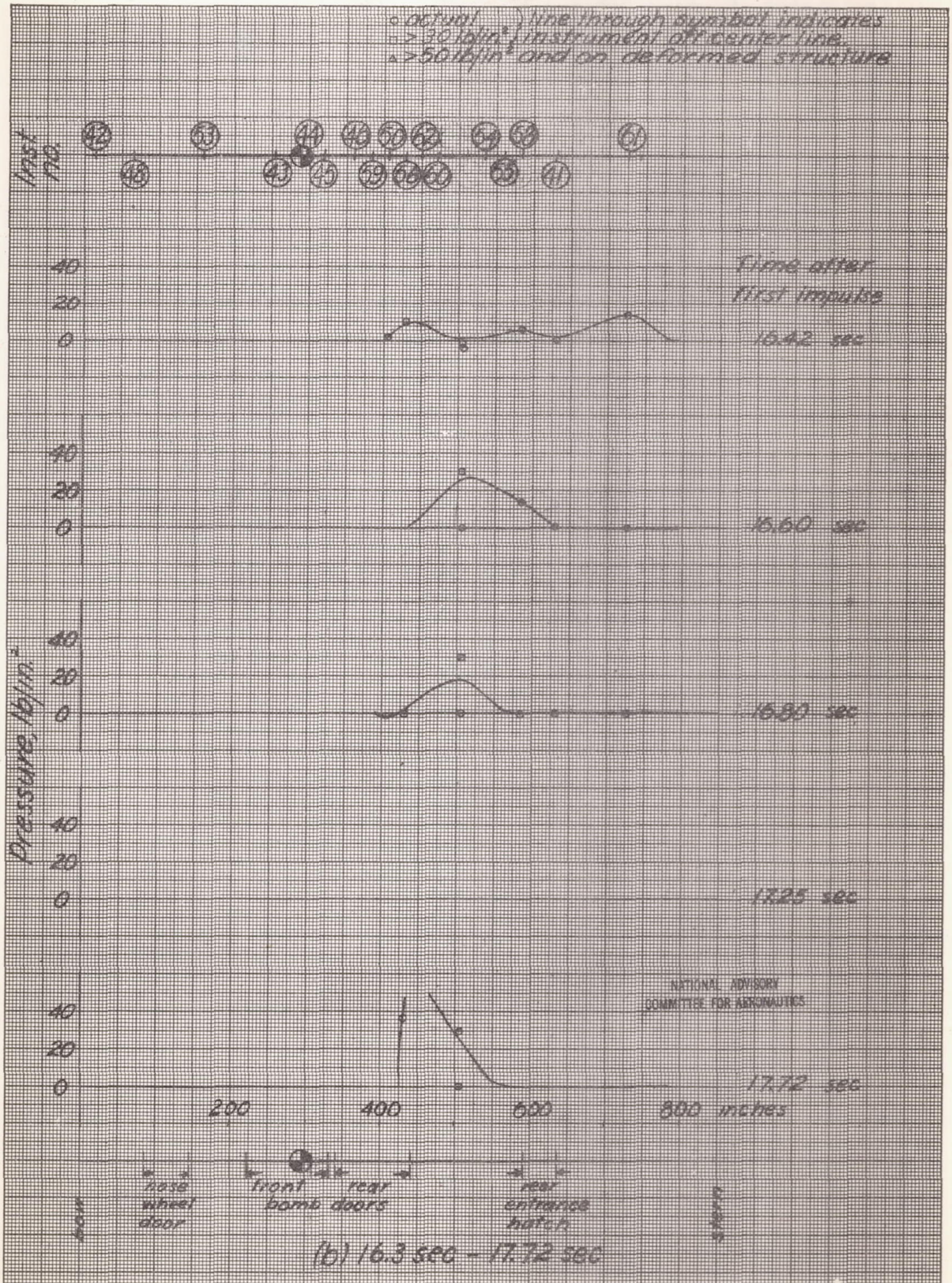

(b) 16.3 sec - 17.72 sec

Figure 14.- Continued.

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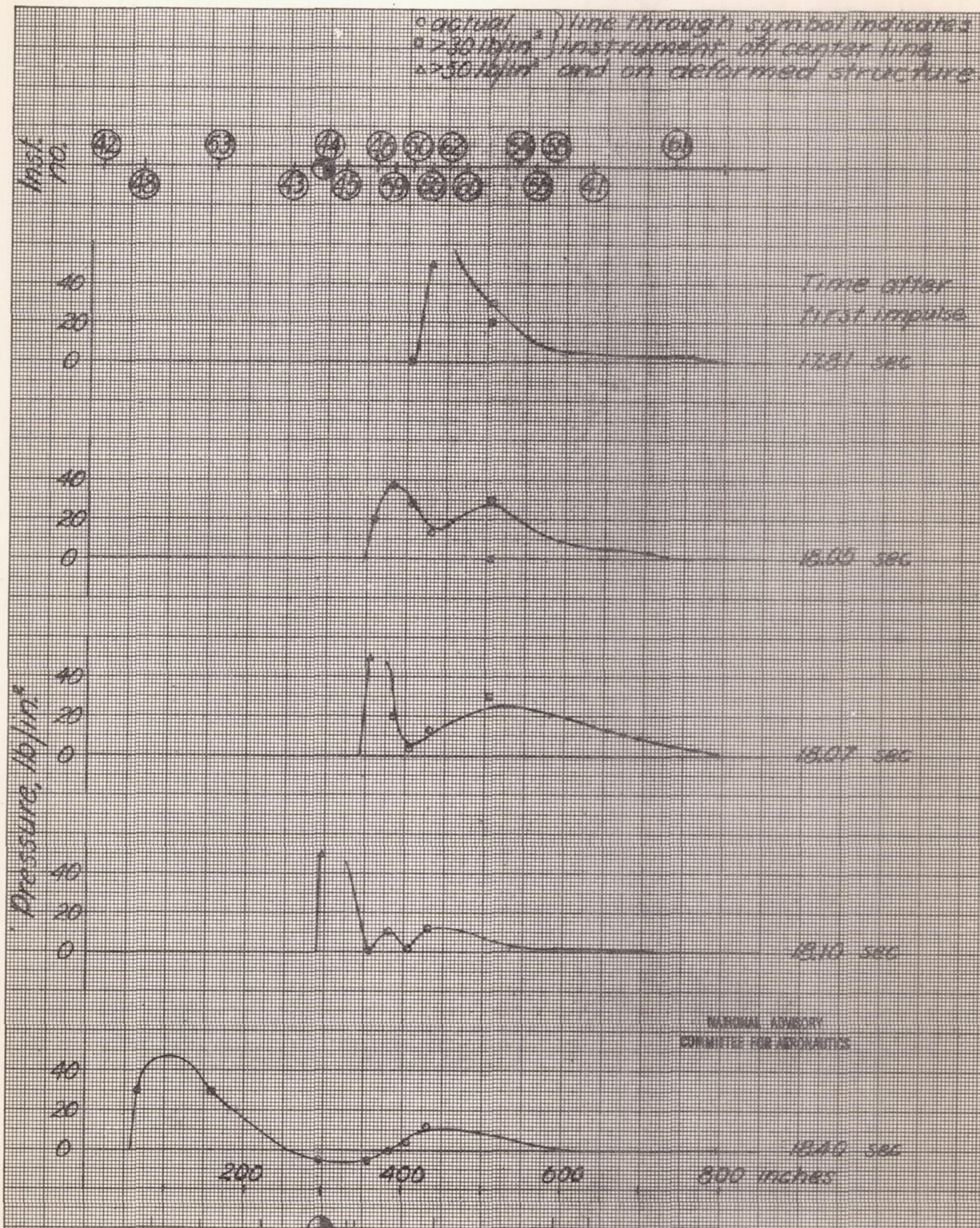

(c) 17.72 sec – 18.40 sec

Figure 14.- Continued.

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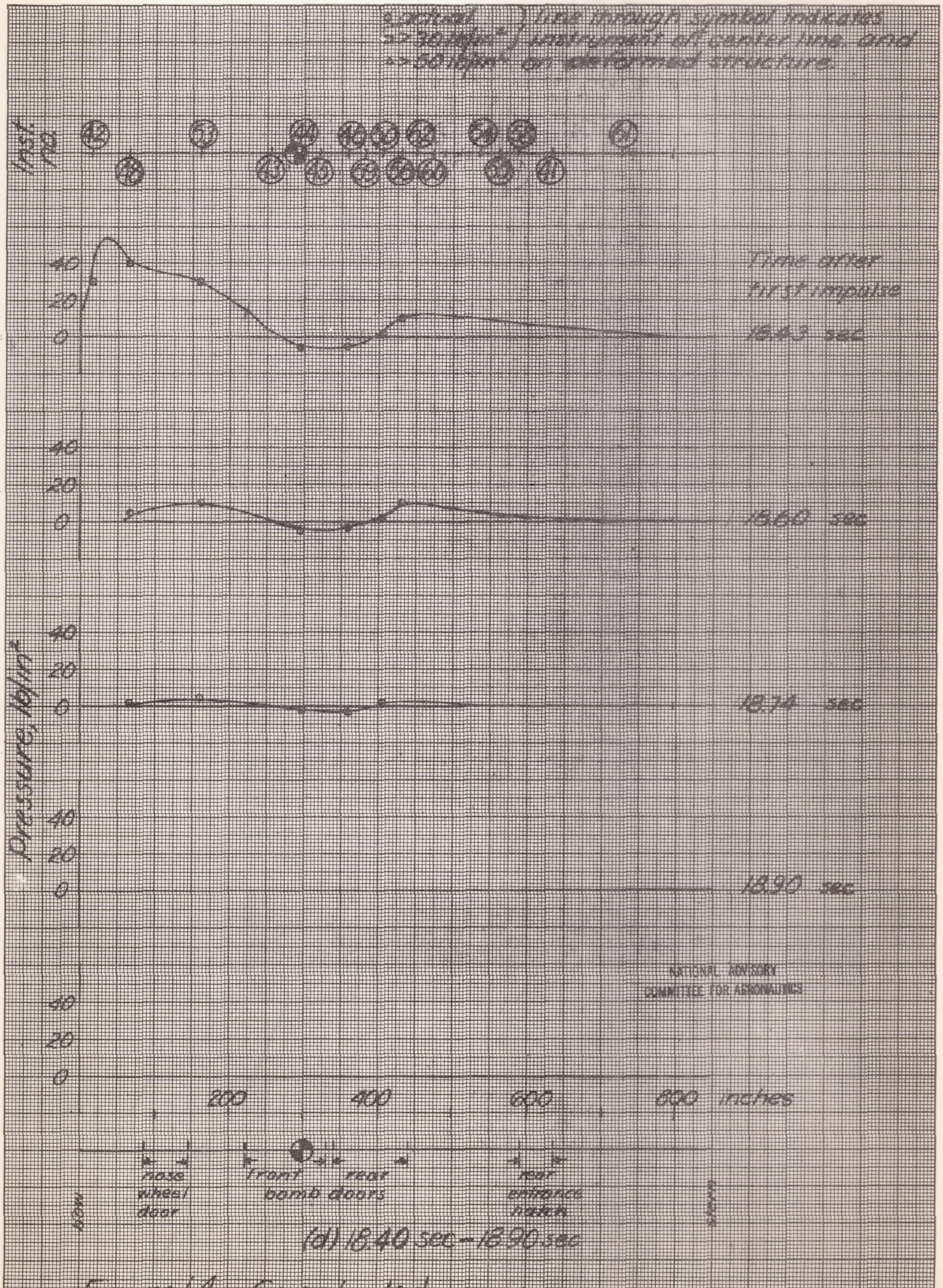

(d) 18.40 sec – 18.90 sec

Figure 14- Concluded

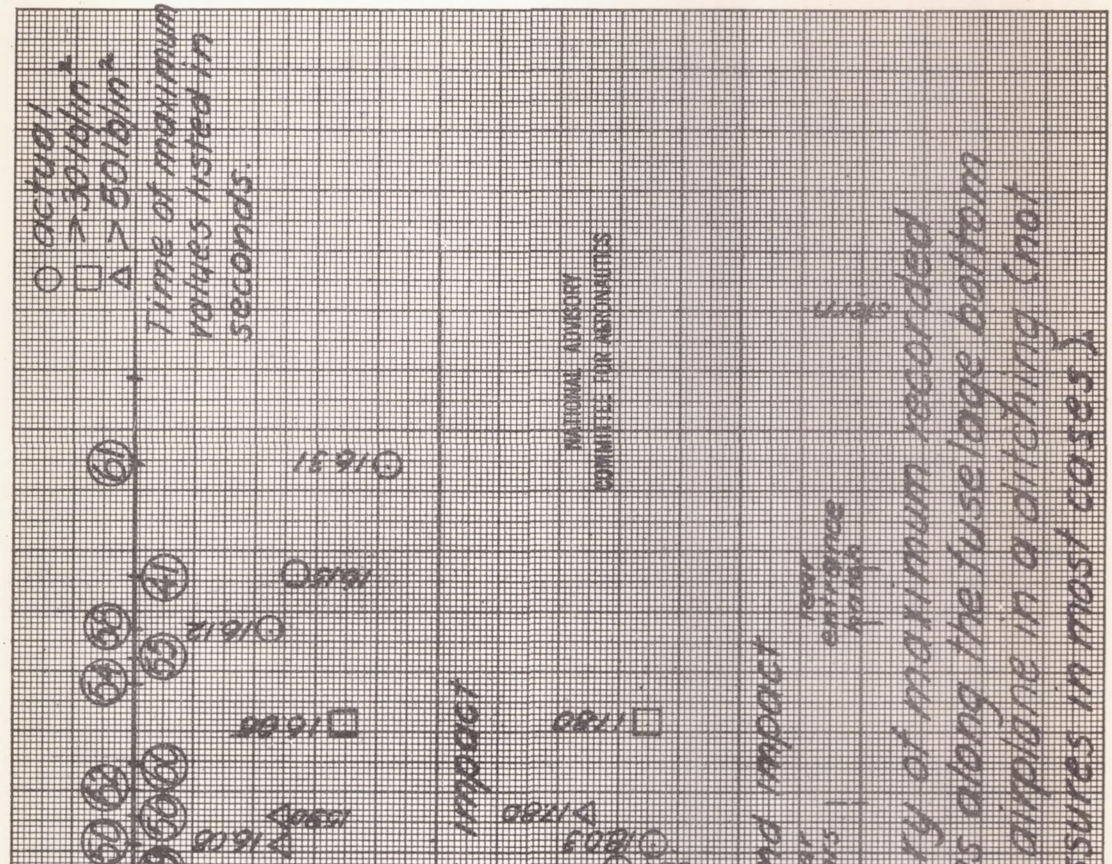

Figure 15.- Summary of maximum recorded pressures along the fuselage bottom of a B-24 airplane in a ditching (not peak pressures in most cases).

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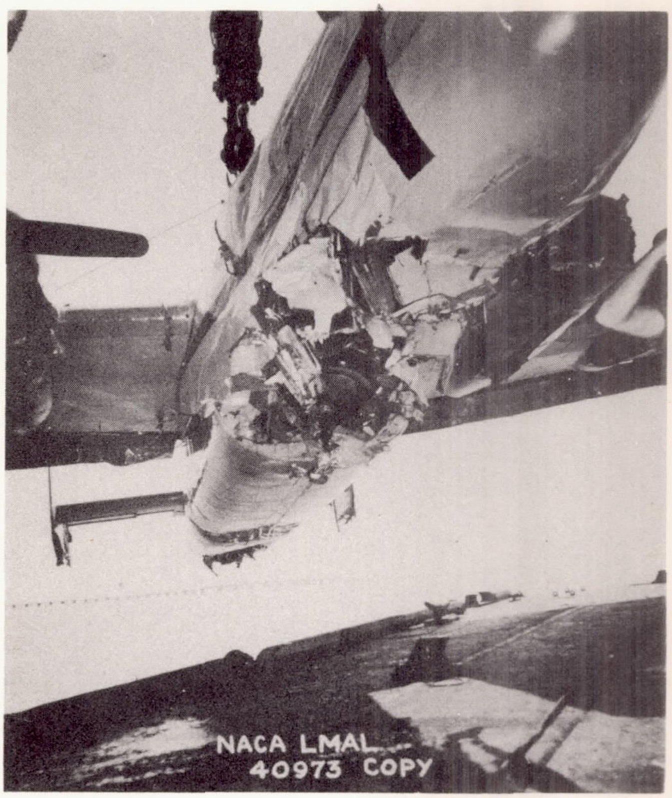

Figure 16.- Photograph of B-24D fuselage bottom taken after airplane was removed from James River. Note damage in nose-wheel door area, dent in rear bomb door, hole near bottom turret, and damage to rudders. The skin was indented over lower half of fuselage in a strip just in front of the tail empennage.